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REPORT

SATELLITE BROADCASTING: an aerial design for domestic reception in the 12 GHz band

No. 1970/27

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

SATELLITE BROADCASTING: AN AERIAL DESIGN FOR DOMESTIC RECEPTION IN THE 12 GHz BAND

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(RA-63)

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Section	Title	Page
	Summary	1
1.	Introduction	1
2.	Requirements	1
3.	The aerial	3
4.	Performance	4
	4.1. Radiation patterns	4
	4.2. Admittance	5
	4.3. Gain	5
5.	Conclusions	5
6.	References	6

(RA-63)

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Summary

A design of aerial suitable for use in Television Band VI (11·7 GHz – 12·7 GHz) is described. The aerial should be capable of mass-production at low cost to meet a possible domestic requirement.

1. Introduction

The possibility of broadcasting from geo-stationary satellites is currently being studied by the CCIR and other bodies. It is likely that such transmissions would be in Television Band VI (11·7 GHz – 12·7 GHz) and would use frequency modulation or pulse-code modulation. The transmissions might be used for the distribution of programmes to area transmitters, for broadcasting to local centres with further dissemination by wire or for broadcasting to individual viewers. The last possibility would be the most demanding in that the receiving aerial would have to be cheap to manufacture and simple to install and this is the application considered in this report.

A viable plan for broadcasting from satellites must take into account the number of channels available in the frequency band and the number of transmissions likely to be required. Unfortunately the latter invariably exceeds the former and any one channel is likely to be shared by several satellites, suitably spaced in orbit. In any given area the level of co-channel interference is then a function of the directivities of the transmitting and receiving aerials. It follows that a good estimate of these parameters is needed at an early stage in order that the planning may proceed. The work described had the objective of establishing the directivity achievable with a receiving aerial which could be mass-produced at low cost.

The basic geometry of transmission from a geo-stationary satellite is shown in Figs. 1 and 2.

2. Requirements

Preliminary studies of broadcasting from satellites have been made in which the receiving aerial has been assumed

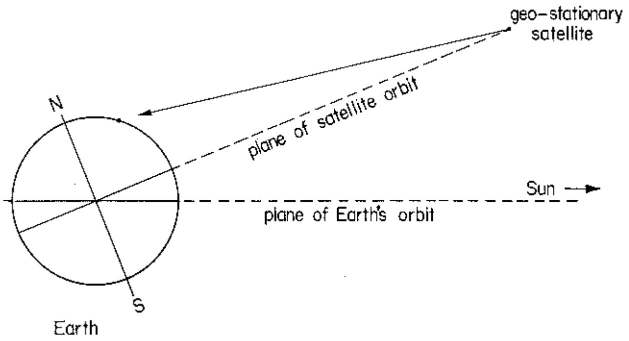

Fig. 1 - Broadcast transmissions from a geo-stationary satellite

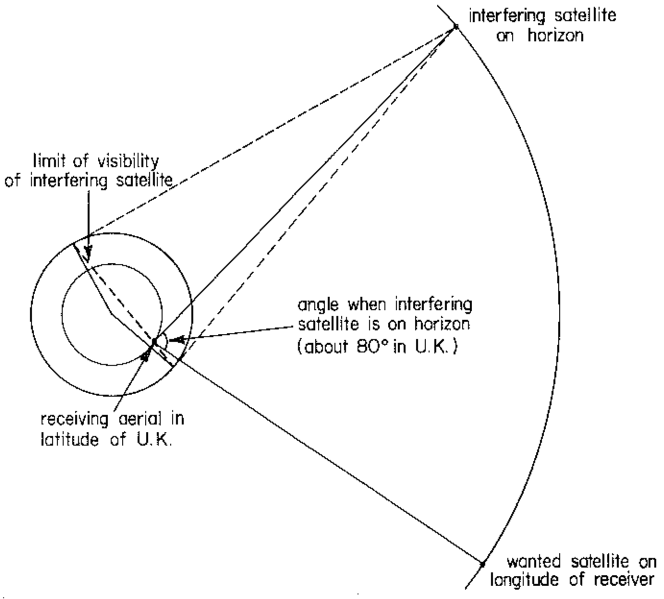
interfering satellite on horizon
limit of visibility of interfering satellite
angle when interfering satellite is on horizon (about 80° in U.K.)
receiving aerial in latitude of U.K.
wanted satellite on longitude of receiver

Fig. 2 - View in equatorial plane

(RA-63)

to be a paraboloid.[1,2] Typical figures for the aerial performance in a system operating at 12 GHz are as follows[1]:—

Aperture:	Circular, diameter 1 m
Maximum effective gain:	39 dB relative to isotropic source
Beamwidth:	1·7°

The effective area, A, of an aerial is given by

$$A = \frac{\lambda^2}{4\pi} g$$

where g is the aerial gain relative to an isotropic source, expressed as a power ratio. Thus an aerial having a circular aperture of diameter 1 m might be expected to have a gain of 42 dB relative to an isotropic source at 12 GHz. In practice the gain will be less than this since it is impracticable to illuminate the reflector uniformly without losing energy past the edges. Typically, the aerial gain will be reduced by about 3 dB on this account, corresponding to an efficiency of illumination of about 50%.

It is convenient in interference studies to use a generalised expression for the discrimination provided by the aerial against signals arriving from directions away from the main beam. Reference 2 gives the following:—

$$10 \log_{10} G(o) - 10 \log_{10} G(\theta) = 15 + 20 \log_{10} (\theta/\phi) \qquad (1)$$

where $G(\theta)$ is the gain at angle θ from the axis, relative to an isotropic radiator and ϕ is the 3 dB beamwidth.

It is assumed in Reference 2 that ϕ, expressed in degrees, is related to the diameter/wavelength ratio d/λ by the expression

$$\phi = 70\ \lambda/d \qquad (2)$$

Equation 1 is applicable only to values of θ greater than one or two beamwidths.

Reference 1 does not give an expression for the discrimination but an associated document[3] gives

$$10 \log_{10} G(o) - 10 \log_{10} G(\theta) = 10{\cdot}5 + 25 \log_{10} (\theta/\phi) \qquad (3)$$

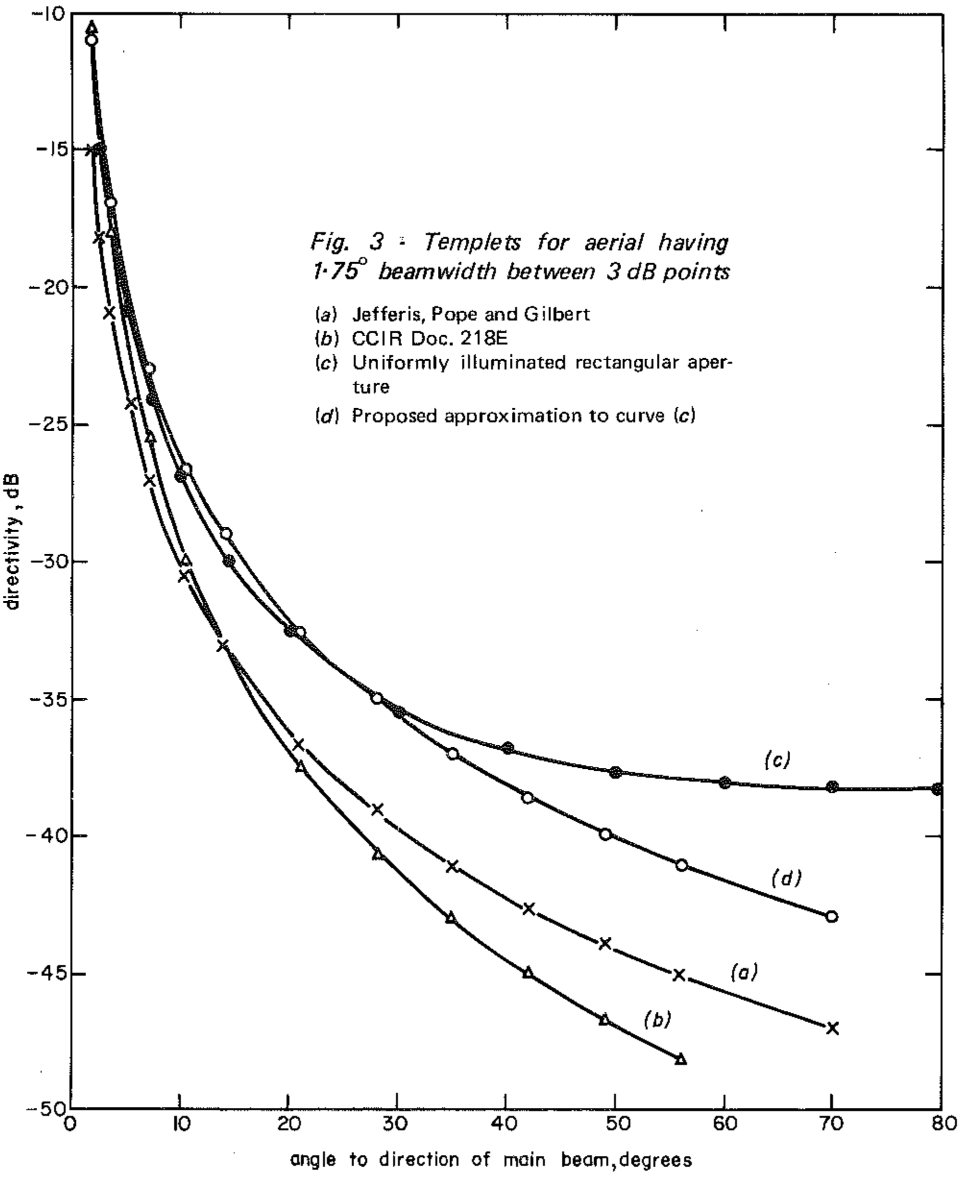

Fig. 3 : Templets for aerial having 1·75° beamwidth between 3 dB points

(*a*) Jefferis, Pope and Gilbert
(*b*) CCIR Doc. 218E
(*c*) Uniformly illuminated rectangular aperture
(*d*) Proposed approximation to curve (*c*)

This expression gives a result at small angles which is close to the performance of a practical aerial.

In Fig. 3 curves (*a*) and (*b*) show that both expressions assume a low side-lobe level at high angles compared with a uniformly illuminated rectangular aperture (curve *c*). This arises since both expressions are based on the paraboloid, an aerial having a circular aperture and an illumination which decreases from the axis to the edge. In order that the design of the receiving aerial should not suffer needless constriction, it would be better to fit the directivity expression to that of the uniformly illuminated rectangular aperture. A possible expression is

$$10 \log_{10} G(o) - 10 \log_{10} G(\theta) = 11 + 20 \log_{10} (\theta/\phi) \qquad (4)$$

This is plotted in curve (*d*) of Fig. 3 where it will be seen that the approximation is close for angles up to 30° from the main beam. The divergence at greater angles is unimportant since the total protection ratio in an f.m. system is only 41 dB[2] and the contribution to this required from the receiving aerial is not likely to exceed 30 dB.

3. The aerial

The type of aerial most commonly used at s.h.f. is the parabolic reflector and the CCIR templet is based on this type. The electrical design of these aerials is well understood so that the problems of applying them to domestic installations are largely economic. It seemed possible, however, that other types of aerial might have some advantage particularly if they took the form of a thin slab.

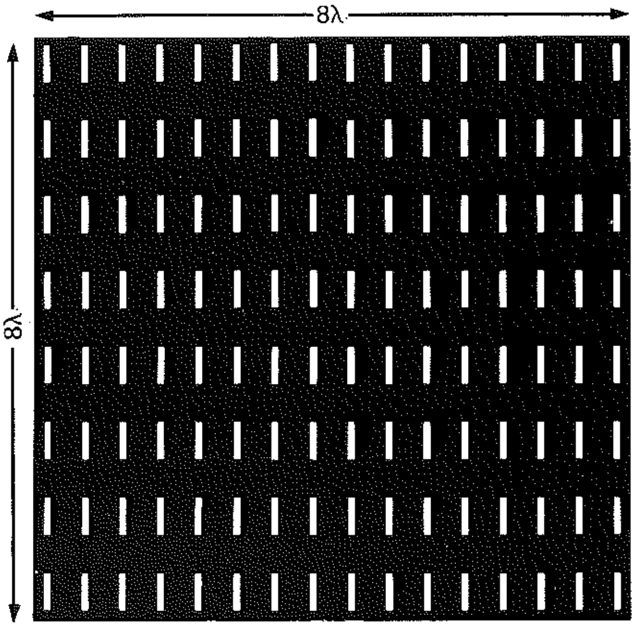

Fig. 4 - Obverse side of printed card

Apart from any possible economic advantage, such an aerial might be easier to install, have less wind loading and be less conspicuous.

The form chosen for the aerial was a planar array of half-wavelength slots printed on a copper-clad laminate (Fig. 4). The slots are spaced approximately one wavelength in the H-plane and one half-wavelength in the E-plane. The aperture of the prototype aerial was 8 wavelengths square; this is less than would be required ultimately, but there should be no inherent difficulty in increasing the aperture.

The reverse side of the board carries the feeding arrangement as shown in Fig. 5. The method by which each slot is fed is the analogue of a half-wave dipole of which only one limb is folded.[4] Pairs of adjacent slots are fed in parallel by a strip line of nominal impedance 100 ohms. Since the slots of one pair are fed from opposite sides it is necessary to arrange a 180° phase difference in the feeds in order to bring the radiated fields into phase; this is done by displacing the tapping point on the 100 ohm line by one quarter wavelength from the mid position. Thereafter the distribution takes the form of a simple branch feeder network with tapered lines used to keep an approximate impedance match. The output was taken to a coaxial connector for convenience in measurement, but it is envisaged that the final aerial could have a mixer and solid-state oscillator mounted on the same printed card. This is desirable since at 12 GHz the loss in a coaxial downlead could be of the order of 20 dB.

The choice of material for the substrate is important. With an aerial having four times the area of the prototype the total length of strip line would be about 0·76 m (30 in.) and the loss in this ought not to be excessive. Unfortunately the common low-loss materials such as polythene

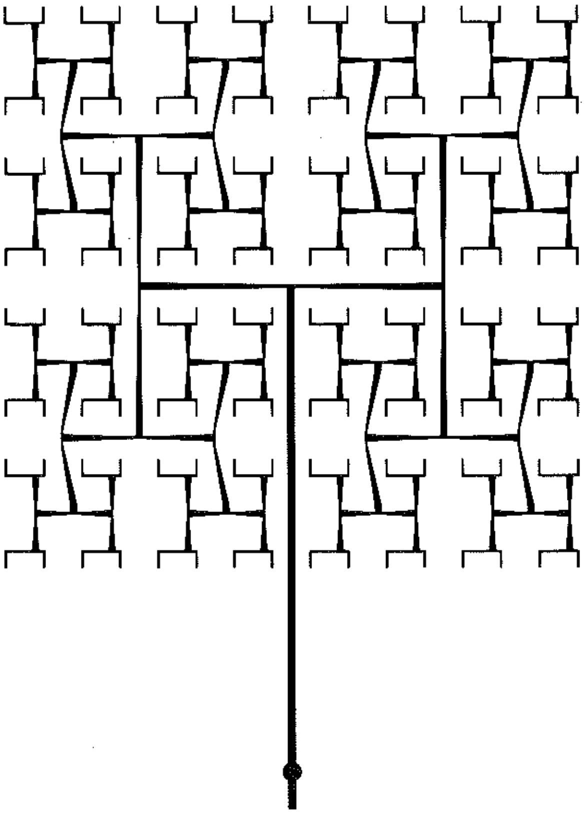

Fig. 5 - Reverse side of printed card

and poly-tetrafluor-ethylene are unsuitable for the production of copper-clad laminates and recourse must be had to other, more lossy, materials. Of these, the most promising were a silicone fibre glass laminate MG 51 costing about £2 per square foot (0·093 m^2) and Rexolite 1422 with an estimated loss half that of MG 51 but costing about £10 per square foot (0·093 m^2). These prices are high but some reduction might be expected if the demand were great. For the prototype aerial MG 51 only was used. The measured attenuation of a 50 ohm line on a 1/16 in. thick laminate was about 4 dB per foot (13 dB/m); this was higher than expected from the manufacturer's information. Thus the loss in the distribution feeder of the prototype aerial was likely to be about 5 dB. Apart from changing the substrate, this loss might be reduced by rearranging the distribution feeder so that the path length to elements in the centre of the array was less than that to elements near the edges; the strip-line attenuation would then be turned to advantage to give a tapered feed with consequent reduction of side-lobe level. The bandwidth of the aerial would be reduced but this may not be important.

4. Performance

4.1. Radiation patterns

The slots were cut to be a half-wavelength at 9·5 GHz, but it was thought that the resonant frequency could be less than this owing to the loading of the dielectric substrate. The spacing between slots in the E- and H-planes was made $\lambda/2$ and λ respectively at 9·5 GHz. The choice of this frequency was dictated by the equipment available for measurements.

The best radiation patterns were observed in the range 8 – 9 GHz but there was some variation of side-lobe levels and symmetry within this range which may be indicative of mismatching in the distribution feeder. Measured radiation patterns in the region of 8·8 GHz are shown in Figs. 6 and 7. These patterns are in fairly good agreement with the predicted side-lobe envelope, shown by the broken lines.

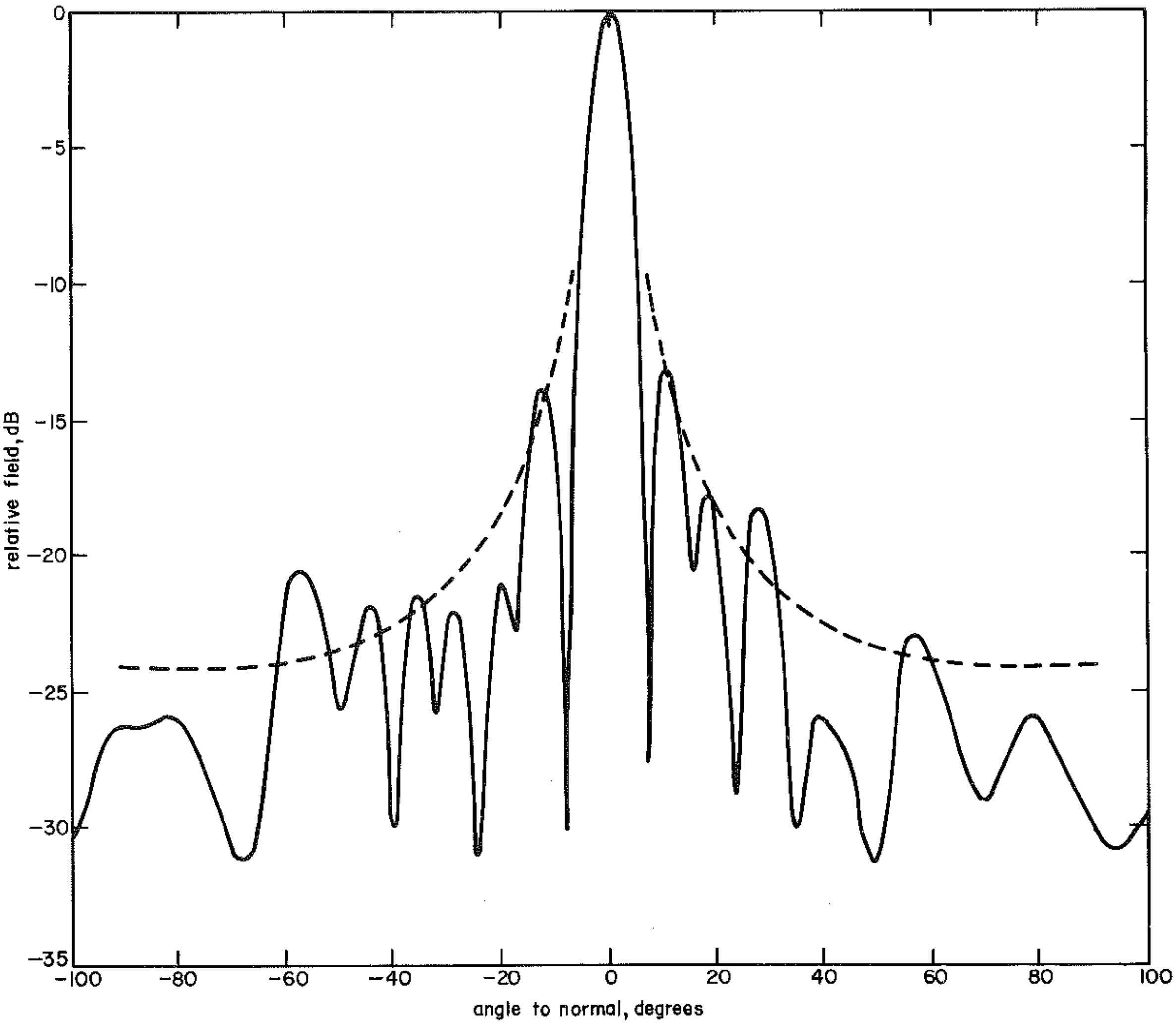

Fig. 6 - E-plane radiation pattern at 8·835 GHz

– – – – – – calculated side-lobe envelope

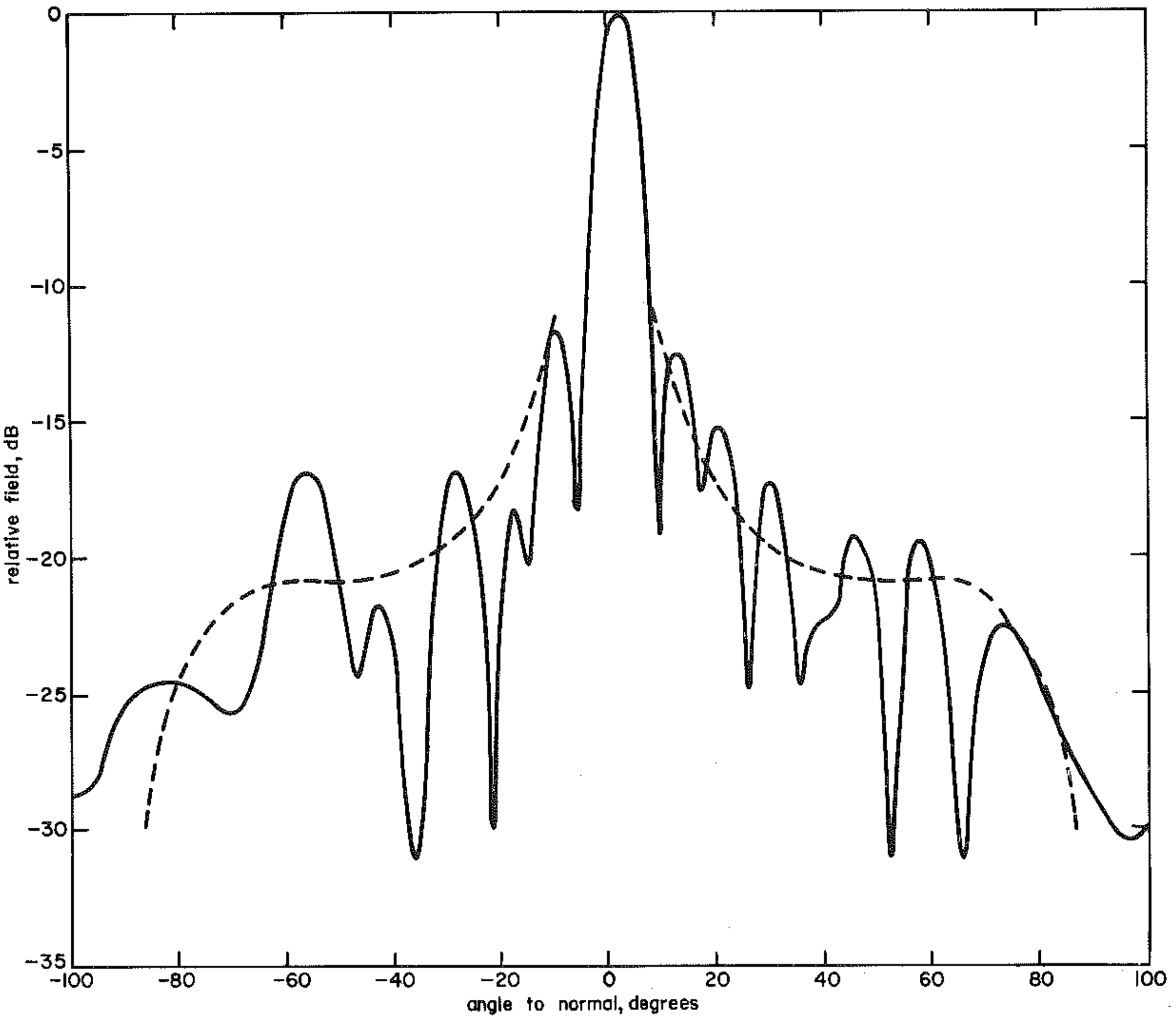

Fig. 7 - H-plane radiation pattern at 8·896 GHz

— — — — — calculated side-lobe envelope

4.2. Admittance

It was not possible to make reliable admittance measurements in the time available owing to discontinuities present in the measuring system, especially at the input connector to the aerial. However, the measurements indicated that the V.S.W.R. was generally not worse than 0·4.

4.3. Gain

Facilities were not available for a direct measurement of the gain of the prototype aerial but an estimate may be made as follows:*

Intrinsic gain of 8λ × 8λ aperture relative to isotropic source		29 dB
Deduct:		
Loss in distribution strip-line	5 dB	
Mismatch loss	1 dB	
Misphasing loss, say,	1 dB	7 dB

Effective gain relative to an isotropic source	22 dB
Effective gain relative to a $\lambda/2$ dipole	20 dB

An increase in the lateral dimensions of four times would increase the intrinsic gain by 12 dB and if the losses are held at the present level, this would give an aerial approaching the assumed requirements. The utilised aperture of such an aerial would be approximately 800 mm (32 in.) square.

5. Conclusions

An aerial design has been produced which is capable of an effective gain of 34 dB relative to an isotropic source at 12 GHz with an aperture of approximately 800 mm square. The level of sidelobes falls off less rapidly with angle than currently assumed in the planning of possible satellite broadcasting, but these assumptions are both optimistic for any cheap, mass-produced aerial and unnecessarily severe. The material used for the experiments was expensive. A cheaper material, preferably with less loss, would be essential for a domestic aerial.

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* A subsequent measurement has indicated that the line and mismatch losses may be higher than estimated here.

6. References

1. Feasibility of sound and television broadcasting from satellites. CCIR Study Group IV Report New Delhi, 1970.

2. JEFFERIS, A.K., POPE, D.G. *and* GILBERT, P.C. 1969. Satellite television distribution : service from geostationary satellites to community antennas in multiple-coverage areas. *Proc.Instn elect. Engrs.*, 1969, **116**, 9, pp. 1501 – 1504.

3. United Kingdom submission to CCIR Study Group IV, Doc. IV/218E, May 1969.

4. MONTEATH, G.D. 1950. Wideband folded-slot aerials. *Proc.Instn elect. Engrs.*, 1950, **97** Part III, 50, pp. 414 – 418.

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